FEASIBILITY STUDY OF LAKE WAVELAND AND ITS WATERSHED MONTGOMERY COUNTY AND PARKE COUNTY, INDIANA

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EXECUTIVE SUMMARY

This Feasibility Study of Lake Waveland and its watershed was conducted in the spring and summer of 1989. The purpose of the study was to identify conditions and practices in the lake and surrounding watershed that were contributing to declining water quality and sedimentation. Elements of the study included

1) A watershed survey to identify land uses, soil types and point and nonpoint sources of pollution

2) A biological and physicochemical survey of the lake and its tributaries

3) Preparation of a report and recommendations

It was found that lake has an IDEM Eutrophication Index of 53 points, which places it in the category of Indiana lakes with the lowest water quality and the highest eutrophication. The sediment and nutrient inputs to the lake appear to be the result of agricultural practices in the watershed. Sedimentation of the embayments is a severe problems at Lake Waveland. The embayments have lost 25 to 36 percent of their volume in the past 19 years, and it is estimated that at an estimated sedimentation rate of 0.1 foot per year, most of the embayments will be filled with sediment within 40 years. The embayment sediments are mainly decaying plant material rich in nutrients, and blooms of algae and macrophytes are common in summer. These reduce access to the embayments and limit use of the lake by the public and by lakeside residents. A series of land treatment measures were recommended for farmland in the watershed in order to reduce the flow of sediment and nutrients into the lake. Many of the measures can be assisted by or cost shared with the county SCS offices. Four lake treatment mitigation measures were discussed as accompaniments to the land treatment measures: no action, weed control, dredging and dredging with retention structures. Without the land treatment measures in place, none of the lake treatments would be effective. In terms of cost and effectiveness, weed control by harvesting and removing them from the lake was recommended.

INTRODUCTION AND STATEMENT OF PROBLEM

The Waveland Parks and Recreation Board has undertaken a Feasibility Study for Lake Waveland and its watershed. Partial funding for Feasibility Studies is provided through the Lake Enhancement Program, a part of the "T by 2000" statewide strategy for dealing with Indiana's soil erosion and sedimentation problems. The Lake Enhancement Program is administered by the Indiana Division of Soil Conservation. The purpose of a Feasibility Study is to identify and quantify water quality problems at a lake, assess the contributions of various factors in the watershed to those problems, and to discuss and recommend potentially feasible solutions to the problems.

Lake Waveland has been undergoing changes in depth and water quality. Symptoms of lake problems include proliferation of aquatic vegetation along much of the shoreline, infilling of embayments, and proliferation of floating and rooted aquatic vegetation in the open water of the embayments and other portions of the lake. This Feasibility Study defines and quantifies some of the ongoing problems at Lake Waveland and assesses the relative contributions to the lake problems resulting from:

- Soil types in the watershed
- Agricultural practices and land use in the watershed
- Residential development near the lake shore line
- Use of Lake Waveland and the park for recreational purposes.

GENERAL DESCRIPTION OF LAKE WAVELAND AND ITS WATERSHED

General

Lake Waveland is located approximately two miles northwest of Waveland, Indiana (Montgomery County) in Sections 21, 22, 27 and 28, T.17N., R.6W. (Figure 1). Although most of the Lake is located in Montgomery County, a portion of the western shore line is located in Parke County. The lake covers about 383 acres at normal pool level, has a gross storage capacity of

About 1,198 million gallons of water, and has a watershed of about 11.3 square miles (Clark, 1980). The watershed is predominantly in agricultural use, and is entirely rural. Lake Waveland is a PL-566 lake that was created by damming Demeree Creek in 1970 by the Little Raccoon Conservancy District in cooperation with the Soil Conservation Service. A portion of the land surrounding the lake is managed as the 248 acre Waveland Park by the Waveland Division of Parks and Recreation, while the lake water and fishery is managed by the Indiana Department of Natural Resources. The park offers boating, canoeing, fishing, swimming and camping to the public and is closed in winter. There is a small waste treatment plant that serves the RV camping area at the park. The plant outfall discharges into a small drainageway leading southerly away from Lake Waveland. There is a lakeside residential development along a portion of the northwest lake shore line in Parke County.

Topography and Relief

The Lake Waveland watershed is for the most part level to gently rolling, except for the portion in Parke County west and southwest of the lake which tends to be more rugged and dissected. The areas of greatest relief are generally near the lake and along streamways. Elevations in the watershed range from 708 feet msl (approximate surface elevation of Lake Waveland) to over 800 feet msl on the highest points at the watershed boundary.

Geology

Bedrock in the area is probably limestone, sandstone and shale of Late Mississippian Age. This is overlain in turn by a thick mantle of unconsolidated Pleistocene Age glacial deposits. Montgomery County well records from the watershed north and east of the lake (Division of Water, 1965) indicate that this mantle of unconsolidated material is at least 90 feet thick in most places. Parke County well records from the watershed west of the lake (Division of Water, 1964) indicates the mantle is 80 to 100 feet thick.

Ground Water

Local water use is primarily supplied by private water wells. The town of

Waveland is supplied by local ground water wells. Wells in Lake Waveland Park for the most part supply adequate water. It was noted, however, that some well water tastes strongly of sulfur.

Surface Water

The lake is supplied from the east by two inlet streams: Spencer Branch and Old Shoe Branch, from the north by the remainder of Demeree Creek and from the west by unnamed intermittent streams with a shorter, higher gradient flow. Most of the watershed drained by Demeree Creek, Spencer Branch and Old Shoe Branch consists of level to rolling farm land. The watershed west of the lake drained by the intermittent streams has a much higher proportion of wooded land. The U.S. Geological Survey has maintained a crest stage gage on one of the intermittent lake inlet streams located west of the lake in Parke County since 1972 (Gage No. 03341150). The gage measures only peak flow for each year. There are no other stream gage data within or near the watershed.

Soils

No published soils survey as yet exists for Montgomery County, but individual soils maps based upon 1975 air photos are available at the local SCS office along with a key to the mapped soils showing acres mapped in the county and projected corn yields per acre. The Parke County soils survey was issued in April, 1967. Soils in the watershed consist of the Miami-Russell-Fincastle-Ragsdale Association (U.S. Geological Survey, 1983). The soils in this Association range from well drained to very poorly drained. They are found on end moraines and rolling areas near streams that dissect glacial till plains. Parent materials are loess and calcareous loam glacial till. The most common watershed soils mapped in Parke County are Russell silt loams, Alford silt loams, and Reesville silt loams. All but the Reesville silt loams present a water erosion hazard. In Montgomery County, Xenia-Birkbeck silt loams, Miami-Xenia silt loams and Reesville-Fincastle silt loams are the most common soils mapped. All but the Reesville-Fincastle silt loams present a water erosion hazard.

Climate

Based on normals for the 1931-1960 period at Crawfordsville, Indiana (approximately 12 miles northeast of Lake Waveland), the average annual temperature for the area was 54.9°F. and the average annual precipitation was 39.49 inches (Division of Water, 1974). The magnitude of a 10-year storm of 24-hour duration is about 4.3 inches; of a 25-year storm of 24-hour duration about 4.9 inches, and of a 100-year storm of 24-hour duration about 6.0 inches (U.S. Geological Survey, 1983).

RESULTS OF PREVIOUS STUDIES

A PL-566 Watershed Study for the Little Raccoon Creek Conservancy District contains some information about Lake Waveland. Studies of the lake have been conducted over the years by DNR Division of Fish and Wildlife personnel. They include a preimpoundment study and initial lake stocking in 1970. Fishery surveys were conducted in 1972, 1973, 1975, 1976, 1978, 1981, 1984 and 1988. There was a selective fish eradication in 1975, and lake drawdowns of 3.5 to 5 feet in 1978, 1979 and 1980 to maintain a good proportion of largemouth bass to bluegill. Another drawdown was planned for 1989. Partial chemical weed control was conducted from 1979 to 1983, and in 1988. The lake is supplementally stocked with channel catfish on a triennial basis, with the last restockings occurring in 1986 and 1989.

The Indiana Lake Classification System and Management Plan lists a Eutrophication Index number for Lake Waveland of 20. This was apparently calculated for the lake in the Mid-1970's soon after its impoundment.

METHODS AND MATERIALS

This study was conducted as three Tasks:

- Task 1 - Lake Waveland Watershed Survey
- Task 2 - Biological and Physiochemical Survey of Lake Waveland and its Tributaries

- Task 3 - Preparation of Report and Recommendations

Task 1

The Lake Waveland Watershed Survey was conducted by

1) Gathering all pertinent watershed data from public agencies, including the Montgomery and Parke County SCS, Montgomery and Parke County Assessor's Offices, Montgomery and Parke County Health Departments, Lake Waveland Park, Indiana Geological Survey, Indiana Department of Environmental Management, Indiana Division of Nature Preserves, Indiana Division of Fish and Wildlife, and the U.S. Geological Survey.

2) Reviewing air photos NAPP 18107-224 18-20 and 77-79 taken in 1987 that were available for review at the Montgomery County SCS office.

3) Conducting a ground reconnaissance of the watershed April 28, 1989.

Information collected included land ownership, land use determined from aerial photographs and ground reconnaissance, soils maps, the presence of any state or federal listed endangered species, the presence of nature preserves or natural areas, the presence of hazardous waste sites or other point sources of pollution, and peak flow characteristics of one of the watershed streams.

Task 2

This task consisted of several elements, each having its own set of methods. These are described below:

Mid-lake Water Column Studies:

At the deepest part of the lake ("A" in Figure 2), two 8-inch Secchi disk readings were made: the depth of disappearance and the depth of reappearance. These were averaged. A Li-Cor Quantum Radiometer Photometer (Model Li-185B) with a Li-Cor Underwater Quantum Radiation Sensor (Model Li-192SB) was used to measure ambient light, the light level at three feet, and the depth of one percent light penetration. These measurements were taken twice and averaged. Profiles of dissolved oxygen and temperature were taken at this location using a YSI Model 51B DO/temperature meter with a 25-foot extension cable.

Two plankton tows were taken at this point using a Birge-style closing net sampler, the first a vertical tow from the five-foot level to the surface and the second a five-foot vertical tow starting below the thermocline and including the beginning of the thermocline. Each tow filtered an estimated 16,525 ml of water. The tows were bottled separately by rinsing the sample net thoroughly with deionized water into a 200 ml plastic bottle. Each sample was preserved with three ml of formalin, labeled and placed in a cooler on Blue Ice. These were returned to the Geosciences laboratory for identification and density determinations. Density was estimated by dispensing 0.1 ml of water from the well-agitated sample bottle onto a slide and covering with a 22 x 22 mm cover slip. Three "+"-shaped transects were taken across each cover slip with an AO binocular microscope using a 15X eyepiece and a 35X objective with a measured width of field of 0.364 mm. The total area of the transects viewed was about 10 percent (or 50 mm^2) of the total cover glass area.

A composite water column sample was collected by taking water samples from the five-foot level, the beginning of the thermocline, and one foot above the lake bottom using a 1.2-L. Kemmerer-style sampler. Samples were added to a clean stainless steel bowl in 650 ml aliquots, then transferred to two 1-L. polyethylene cubitainers. The contents of each cubitainer was preserved with 3 ml H_2SO_4, placed in a cooler on Blue Ice, returned to the Geosciences laboratory where it was prepared and shipped to ECI Laboratory of Clarksville, Indiana for determination of Total Phosphorus (soluble phosphorus was omitted by error), Total Kjehldahl Nitrogen (TKN) and Ammonia. An additional 250-ml container was filled with water, labeled, and returned unpreserved in the cooler to the Geosciences laboratory where it was analyzed for Nitrate within 24 hours.

Shore Line and Wetland Features:

Shore line, near shore and wetland features were noted by surveying the shore line on foot and by boat. These included dwellings, in-lake recreation features, crop land, stream obstructions and other features, lake access points, bridges and causeways, and wetlands. These are presented on a map of the lake and surrounding land at a scale of 1"=500′ (Plate I).

Embayment Depth Profiles:

These were conducted at the six locations "T" in Figure 2. A transect line marked in 10-foot intervals was pulled across each embayment and anchored on each shore line with steel fence posts. Depth and sediment thickness measurements were made at 20-foot intervals along the transect line using a 15-foot, 3/8 inch steel probe with an attached tape graduated in 0.01 foot intervals. The probe was lowered into the water until it touched bottom. The depth was measured, then the probe was pushed through the soft sediment until refusal, and the depth was again measured. The depth of refusal of the probe was interpreted to be the original preimpoundment soil surface. At the point of maximum sediment thickness, at least three core samples were taken at successive depths. These were placed in a large stainless steel bowl, mixed, then placed in a clean quart jar, labeled, and placed in a cooler on Blue Ice. These were returned to the Geosciences laboratory, then shipped to ECI Laboratory in Clarksville, Indiana for analysis for Total Phosphorus, TKN, Ammonia and Nitrate. In addition, one 2-L. grab sample of lake water was collected one foot below the water surface, preserved with H_2SO_4, and sent to ECI for determination of Total Phosphorus, TKN and Ammonia. Nitrate was determined at the Geosciences laboratory on an unpreserved sample within 24 hours of collection.

Influent Stream Measurements:

The major influent streams (Demeree Creek, Old Shoe Branch and Spencer Branch ("C" in Figure 2) were to be gaged using a Modified Parshall Flume during a period of normal flow. Three additional points "D" plus points "C" (Figure 2) were to be gaged during a storm event. For each site gaged, water samples were to be taken, prepared and analyzed for the same parameter set described in the preceding section. In addition, a sample was taken from each point gaged, and analyzed for Total Suspended Solids (TSS).

Departures From Study Proposal

A number of the methods proposed for this project were changed in the field. These are discussed below.

1) Nitrate was originally to be analyzed by the ECI Laboratory. Because Nitrate must be analyzed within 24 hours of collection, this was impractical and the samples were analyzed by Geosciences using Ion Chromatography (IC).

2) A paper copy of a recent air photo was found to be too "busy" to effectively display shore line and near shore features. An outline of the lake at 1"=500' gives much better results.

3) Instead of 2-L. containers for water samples, two 1-L. cubitainers were used for each sample collected. These were much easier to store and ship.

4) Because the bottoms of the embayments were found to be quite smooth, 20-foot intervals were chosen for depth measurements instead of 10-foot intervals. The 10-foot intervals added very little new information and would have doubled the time to do each transect.

5) The DO probe was damaged, so DO measurements from a depth of one foot were not taken in the embayments. These data would have been interesting to have but are not required by the Lake Enhancement program, nor are they critical to this study.

6) A 25-foot rather than a 30-foot extension cable was available for use on the DO probe. This resulted in the loss of the two deepest data points for the DO/Temperature profile. Since these were well below the thermocline, these points were not critical to this study.

7) A Modified Parshall Flume was used for stream gaging rather than a

Pygmy Meter because of the nature of the stream bottom profiles. A flume installed by a knowledgable person gives results equal to or superior to those of a Pygmy Meter.

8) The storm event flow measurements were done by Geosciences personnel rather than park personnel since a storm event occurred on the day originally planned for collecting water column measurements from the lake.

9) Only one of the inlet streams to be gaged for normal flow was flowing (Demeree Creek).

10) Old Shoe Branch could not be gaged by flume or Pygmy Meter during the storm event because it had overtopped its banks.

11) For clarity, wetlands will be discussed in a separate section of this report rather than as subsections of the sections dealing with open lake water or embayments.

RESULTS AND DISCUSSION

Land Use and Watershed Features Affecting Lake Water Quality

Table 1 presents a list of the soils mapped within the watershed of Lake Waveland both in Montgomery County and Parke County. Soils have been classified in the table in terms of their water erosion hazard, which are based on USDA Soil Interpretation Records. Soils for which any water erosion hazard or limitation is listed are noted "E". Soils for which no water erosion hazard is listed are noted "N". In Parke County, only Gennessee silt loam, Ragsdale silt loam, and Reelsville silt loam have no water erosion hazard. In Montgomery County, only Beckville loam, Ragsdale silty clay loam and Reesville-Fincastle silt loams were without water erosion hazard.

Before describing the features of the watershed, it may be of use to explain what features and land uses were not found in the watershed:

- Industrial or business facilities
- Urban areas
- Landfills, dumps, wastewater treatment plant outfalls, large feeder lots or other point sources of pollution
- Ongoing or recently completed large construction projects
- Natural areas, nature preserves or records of state or federal rare or endangered species
- Irrigation areas
- Areas of land application of sludge
- CERCLIS (potential hazardous waste) sites
- Any other areas where hazardous materials have been reported to be a problem.

The following land uses were found within the Lake Waveland Watershed:

- Recreation (boating, fishing, camping, picnicking and swimming in Lake Waveland Park)
- Row crops (primarily corn and soybeans)
- Other agricultural land (pasture and hay, fallow land, small hog operations)
- Wood lots and forested land
- Farm houses
- Residential development.

For the purposes of this study, land uses in the watershed will be discussed in terms of row crop and non row crop uses.

Figure 3 shows the Lake Waveland watershed and subwatersheds. "N" soils (soils with no listed erosion hazards or limitations) and "E" soils (soils with listed erosion hazards or limitations) are outlined, and overlain by row crop and non row uses of those soils. Table 2 presents a summary of "N" and "E" soils that are in row crop and non row crop land use for each of the seven subwatersheds and for the entire watershed. Areas were determined by measurement with a compensating polar planimeter on Parke County soils maps (1"=1667') and Montgomery County soils maps (1"=1320'). The entire watershed contains about 5051.4 acres of "E" soils (73.8 percent) and about 1794.6 acres of "N" soils (26.2 percent). The actual area of "E" soils may be about 2 to 3 percent greater, by this definition, because of the presence of 2 to 3 percent slopes on Reesville-Fincastle silt loams. About 4920.2 acres are in row crops (71.8 percent) and 1925.8 acres (28.2 percent) are in non row crop. About 68.6 percent of "E" soils are in row crops and about 81.0 percent of "N" soils are in row crops. Subwatershed VII has the smallest proportion of "E" soils in row crop (24.7 percent) while subwatershed V has the highest proportion of "E" soils in row crop (90.5 percent).

Vintage aerial photographs were examined to determine if major changes in land use had occurred in the past. Air photos BWJ-2DD 1 - 7 and 49 - 54 and BWJ-1DD 257 - 260 were taken 6-22-63. Examination of these photos indicated that most of the area now occupied by Lake Waveland Park was in row crop. The land use of the rest of the watershed was essentially unchanged. Air photos BWJ-2G 72 - 75, 100 - 104 and 149 - 153 were taken 6-30-50. Land use was essentially unchanged, however it was noted that a number of small areas of pasture in the 1950 photos were wooded in the 1963 photos. The Montgomery County District Conservationist reports that since the mid-1960's, several acres of rotational wheat and hay have been lost, and cattle operations have also declined

Land use immediately around Lake Waveland is shown in Plate I. There are about 55 acres in lake shore residential development in Sections 21 and 28, T.17N., R.6W. All of the homes in the development are on septic systems which are for the most part built in Alford silt loams that offer slight limitations for septic tanks due to moderately permeable soil materials. Lake Waveland Park uses holding tanks for its sewage, except for the trailer camping area in the SE quarter of Section 27, T.17N., R.6W. which has a separate waste water treatment plant the outfall of which drains south away from the lake. There is a small fish cleaning station near the boat launching ramp that washes the remains into a drain that connects with the lake. Lake Waveland Park also contains some land which it leases for farming.

In terms of impact on lake water quality, row crop land use appears to offer the greatest potential for delivering large loads of sediment and nutrients to the lake. Row crop use covers over 70 percent of the watershed and occupies the majority of both "E" and "N" soils. It was noted during the watershed reconnaissance conducted April 28, 1989 that much of the land east of the lake was freshly plowed, and that plowing often passed over and through small swales and drainageways that provided for field surface drainage. It appeared that much less land had been plowed west of the lake at that time. There was a noticeable difference in the clarity of the water in the streams draining subwatersheds east and west of the lake. Those streams draining areas V and VI were clear while those draining areas I, II and III were very turbid. There is a beaver dam as of this writing located just upstream of the crossing of the area V stream by Montgomery County Road 950S. Water both entering and leaving the beaver pond was relatively clear.

There have been no records of violations by the waste water treatment plant at the park, nor have there been health problems or complaints associated with the septic systems in the residential area. So long as the holding tanks are drained regularly and maintained properly, they should present no major threat to lake water quality.

<u>Lake Waveland Water Column</u>

<u>Dissolved Oxygen and Temperature Profiles:</u>

Figure 4 illustrates the DO and temperature profiles taken at point "A" (Figure 1) on August 23, 1989. The measured depth at "A" was 29.5 feet.

There is a thermocline at the 15-16 foot level in which DO drops from 9.7 mg/L to 3.2 mg/L and temperature drops from 22.5°C to 20.5°C. DO values remain more or less the same beneath the thermocline while temperature continues to decrease slowly with depth.

Suspended Materials and Light Penetration:

Figure 4 also shows the average depth of Secchi disk disappearance (2.3 feet) and the average depth of one percent light penetration (7.3 feet). These readings approximately bracket a slight decrease in DO between 3.0 feet and 6.0 feet. The percent light transmission at 3 feet was 6.1 percent (40 micromoles $m^{-2}sec^{-1}$ vs. 650 micromoles $m^{-2}sec^{-1}$).

Algae:

Table 3 lists the phytoplankton species and relative abundances found above and below the thermocline. Blue-green algae predominated above and below the thermocline both in terms of total numbers and numbers of species present. They comprised 87.6 percent (6 species) of the algae found above the thermocline and 100 percent (5 species) of those found below the thermocline. The most common species of blue-green algae above the thermocline was Oscillatoria sp. (51.3 percent) and Gloeotricha sp. (59.2 percent) below the thermocline. Green algae comprised only 11.6 percent of the individuals present above the thermocline with Bumillaria sp. being the most common (8.0 percent). Estimated density at 0-5 feet is 11,300 per ml. Estimated density at 16-21 feet is 20,100 per ml.

Chemistry of the Water Column:

Table 4 present a summary of all analytical data for this study. The only value for the water column (A) above detection levels is TKN (2.94 mg/L). It is possible that there had been some dilution of nutrients by influent storm waters. It should be noted that the water collected from the lake bottom at "A" by Kemmerer sampler had a distinct rotten egg odor (hydrogen sulfide). The detection limits for the analyses in Table 4 were those used for wastewater analysis. For this reason, total phosphorus, ammonia and nitrate did not exceed detection levels. To calculate a Eutrophication Index (next section) some assumptions had to be made regarding the values of those parameters.

Eutrophication Index:

The ISBH Lake Classification System was used to calculate a Eutrophication Index (EI) for Lake Waveland. The parameters, ranges and Eutrophy Points, as determined by this study are summarized as follows:

Parameter and Range	Eutrophy Points
1. Total Phosphorus	
0.06 to 0.19 ppm (assumed)	3
2. Soluble Phosphorus	
at least 0.03 ppm (assumed)	1
3. Organic Nitrogen	
2.0 ppm or more	4
4. Nitrate	
0.4 to 0.8 ppm (assumed)	2
5. Ammonia	
at least 0.3 ppm	1
6. Dissolved Oxygen - Saturation 5 Feet From Surface	
115% to 119%	1
7. Dissolved Oxygen - Percent of Water Column With at Least 0.1 ppm	
66% to 75%	1
8. Secchi Disk Penetration	
less than 5 Feet	6

9. Light Transmission at 3 Feet
   0 to 30% 4

10. Plankton - 5 Feet to Surface
   more than 95,000/l; blue-green
   predominate 15

   Plankton - 5 Foot Tow Including
   Beginning of Thermocline
   more than 285,000/l; blue-green
   predominate 15

Based upon the data presented in preceding sections, a Eutrophication Index of 53 was calculated for Lake Waveland. The Index, which gives EI scores ranging from 0 (least eutrophic) to 75 (most eutrophic) offers a means of comparison between lakes. Lake Waveland is a Class 3 Lake (EI between 51 and 75), which includes lakes with the lowest water quality and the most advanced eutrophication. These lakes typically have one or more uses impaired. Blue-green algae are dominant and nuisance blooms of algae and macrophytes often occur during most summer months. Bottom sediments usually consist of decomposing algae and macrophyte remains and are rich in nutrients. Fish kills from oxygen depletion may occur.

<u>Discussion</u>:

The Lake Waveland water column gives every evidence of being highly eutrophic when the data presented in this section are compared with the ISBH Eutrophication Index (EI) criteria (Indiana Stream Pollution Control Board, 1976). For the organic nitrogen criterion, values above 2.0 mg/L contribute the most points to the EI. TKN exceeds this value. On the other hand, more than 70 percent of the water column had at least 0.1 ppm of DO which is not consistent with eutrophic conditions. Secchi disk visibility of five feet or less and percent light penetration at three feet of 30 percent or less are both indicative of highly eutrophic conditions. Values for both parameters in the water column were both less than these critical values. The plankton densities from five feet to the surface exceed 10,000 organisms/ml and are heavily dominated by blue green algae. The plankton densities from 16 to 21 feet exceed 20,000 organisms/ml and consist entirely of blue green algae.

The lake level may be as much as two feet higher than other years because of persistent and heavy rains that have occurred in the spring and summer of 1989.

Embayments

Bottom Profiles and Depth of Sedimentation:

Bottom profiles and depth of sedimentation for each of the six transects are shown in Figure 5. The transect showing the least sedimentation problem was No. 1, just west of the causeway (Figure 2). The mean sediment thickness was 0.7 feet and the mean water depth was 9.5 feet. By contrast, the mean sediment thickness of transect No. 6, just east of the same causeway, was 2.1 feet with a mean water depth of 3.7 feet. The rest of the embayments had sediment thicknesses that ranged from 1.7 feet to 2.25 feet. The maximum sediment thickness encountered was 5.8 feet in transect No. 6. All sediments collected were black, gritty, and had a viscous, almost jellylike consistency. There was a great deal of organic material incorporated into the sediments, and many smelled of hydrogen sulfide.

Based upon an impoundment period of 19 years, the following sedimentation rates can be estimated for each of the transect embayments:

Transect No./Embayment	Estimated Mean Sedimentation Rate (Ft./yr.)
T-1	0.04
T-2	0.09
T-3	0.09
T-4	0.11
T-5	0.12
T-6	0.11

Overall, sediment appears to accumulate in the embayments at a rate of about 0.1 foot/year. An exception is at Transect No. 1 located west of the causeway, where the accumulation is about 0.04 foot/year. This indicates that the causeway has to some extent operated as a sediment barrier and has prevented much of the sediment carried down Old Shoe Branch from entering the lake proper.

Water and Sediment Chemistry:

Table 4 shows both the water chemistry and sediment chemistry of the embayments (T-1 through T-6). For Total Phosphorus T-6 (Old Shoe Branch) has the highest values both for water (1.556 mg/L) and sediment (16.172 mg/kg). For TKN, the highest sediment value is at T-3 (Spencer Branch - 580.62 mg/L) and the highest water value is at T-1 (Old Shoe Branch - 4.00 mg/L). Ammonia was not detected in any of the water samples, and the highest sediment value was reached at T-5 (73.88 mg/kg). For nitrate, the highest water value was at T-6 (7.6 mg/L) and the highest sediment value was at T-4 (Demeree Creek - 309.90 mg/kg). Values at T-6 were consistently higher than at T-1, except for TKN.

Chemistry and Total Suspended Solids in Influent Water:

Table 4 shows water chemistry data for C-1 (Figure 2) for regular flow taken August 21, 1989, and for C-1 to C-3 and D-1 to D-3 for a storm event on August 22, 1989. On August 21, 1989, only C-1 (Demeree Creek) was flowing. C-2 (Spencer Creek) contained some standing water and C-3 (Old Shoe Branch) was floored with hummocky sand between which were standing pools of water. According to Joe Jarvis of radio station WCVL in Crawfordsville, 1.3 inch of rain fell at Crawfordsville on August 22. During the storm event, Old Shoe Branch overtopped its banks and could not be gaged by any method. However, a water sample was collected.

At Demeree Creek (C-1), the water flow increased almost sixfold during the storm event, and Total Suspended Solids (TSS) increased eightfold. Total phosphorus remained essentially unchanged while TKN increased twofold and nitrate increased threefold (ammonia was unchanged).

During the storm event, the highest value for Total Phosphorus was 1.778 mg/L at C-1. The highest value for TKN was at D-1 (5.04 mg/L) and the highest value for Nitrate was at C-1 (4.2 mg/L). TSS ranged from a high value of 780 mg/L at D-3 to a low of 100 mg/L at C-1. The lowest TSS values were found at C-1, C-2 and C-3 (100 to 400 mg/L) and the highest values were found at D-1, D-2 and D-3 (410 to 780 mg/L).

Storm flow was remarkably uniform considering the difference in watershed areas. The highest flow was in Demeree Creek (0.483 cfs), which has a drainage area of 1537 acres. This was followed by the flow at D-3 (0.470 cfs) which drains a watershed of only 405 acres. The largest streams were gaged first and the discrepancy may be attributable to slower response times for the streams in the larger watersheds.

Discussion:

All of the embayments investigated show signs of considerable sediment input over the 19 years of the life of this impoundment. It is estimated that the embayments have lost 25 to 36 percent of their water volume during this period. The depth of sedimentation at the deepest part of the lake is unknown. At a sedimentation rate of 0.1 foot per year and a mean embayment depth of 4 feet (excepting Transect No. 1), it might be predicted that within 40 years all of the lake embayments will be completely filled in, except in the vicinity of Transect No. 1. This ignores the effects of accelerated wetland development which would hasten infilling by trapping more sediment and depositing decayed plant material.

The sediments investigated all contain large amounts of nutrients, and a great deal of organic material in various states of decay. They are very loose in consistency and any disturbance of the bottom would serve to put large amounts of sediment and finely divided plant materials into the lake water. Such disturbances might include storm event inflows, lake overturn, and wave action close to the shoreline.

The waters of the embayments contain significantly higher amounts of nutrients than does the water column at "A". There is no indication that one embayment contains significantly higher levels of nutrients in the water or sediment, although storm waters in Demeree Creek contained the greatest amounts both of Total Phosphorus and TKN for the event observed. Likewise, the mean sediment thicknesses of the embayments are similar with the exception of T-1, which is protected by the causeway. It should be noted that the embayment at T-2, which is surrounded by the housing development had no high values in either the sediment or the water for any of the nutrients measured.

At this time, the embayments are to some extent acting as traps for the sediment and nutrients entering Lake Waveland from the surrounding watershed. Nutrient and sediments are being held in these rather than entering the main body of the lake. No single influent stream was contributing more nutrients than the others, during the storm event, but overall, the three perennial streams (C-1, C-2 and C-3) will contribute more nutrients to the lake than the intermittent streams both because of longer flow times, and because there will be more water flowing through those embayments to carry nutrients out into the lake.

Wetlands

Description of Wetland Types:

Wetlands at Lake Waveland are divided into Lacustrine and Palustrine types (Cowardin, et al, 1979). Lacustrine wetlands extend from the lake shore line out into the lake and includes the lake's littoral (near shore) zone. It can be subdivided into persistent and nonpersistent wetlands. Nonpersistent lacustrine wetlands are generally in deeper water and contain rooted and/or floating aquatic plants that fall to the lake bottom or die back at the end of the growing season. This group is composed of the aquatic "weeds" which grow profusely most summers and prohibit use of portions of the lake, particularly the northern and the embayments. At Lake Waveland in the summer of 1989, nonpersistent wetlands chiefly contained the following species:

Jussiaea repens - creeping waterprimrose
Potamogeton nodosus* - American pondweed
Lemna minor - duckweed
Ceratophylum demersum* - common coontail
Elodea canadensis - American elodea
(* - common)

Persistent lacustrine wetlands are generally located in the water adjacent to the shore line and consist of rooted plants that normally remain standing until at least the following growing season. At Lake Waveland in the summer of 1989, persistent wetlands consisted almost entirely of cattails (Typha latifolia). Also present at a few places were bulrush (Scirpus sp.) and giant reed (Phragmites australis).

Palustrine wetlands as defined for this report are mostly situated outside the lake shore line and are mostly dominated by woody vegetation. Most of the areas where this wetland type occurs now were not wetland areas in the past, but were probably comparatively well-drained valley sides and hill slopes. In such areas, the dominant woody vegetation is sandbar willow (Salix interior) with little in the way of understory growth. An exception is the forest around the mouth of Demeree Creek which probably could have been termed a swamp forest before the creation of Lake Waveland. There, the dominant trees consist of the following:

Fraxinus pennsylvanica - green ash
Salix nigra - black willow
Robinia pseudoacacia - black locust
Platanus occidentalis - sycamore
Acer rubrum - red maple
Acer negundo - boxelder
Morus rubra - mulberry
Juglans nigra - black walnut

One additional area mapped as palustrine for this report is found where a field drainage ditch enters the lake on the east side about 500 feet north of Montgomery County Road 950S. There is a mud flat extending into the lake from the ditch that contained no vegetation. Along the ditch edges, the dominant vegetation was smartweed (polygonum sp.) and sandbar willow.

Wetland Distribution:

Plate I shows the distribution of wetlands around Lake Waveland. A total of 87.12 acres of wetlands were mapped, of which 45 acres (51.6 percent) are Lacustrine - persistent wetlands; 8.38 acres (9.7 percent) are Lacustrine -

nonpersistent wetlands; and 33.74 acres (38.7 percent) are Palustrine-wooded. The most extensive wetlands occur near the mouth of Demeree Creek. The inlet at stream sampling point D-1 is also complex, owing to the presence of a beaver dam and pond. The wetlands along the shore of the main lake are less extensive on the east side than on the west and nonpersistent lacustrine vegetation was not noted to any great extent on the eastern shore. This is probably because of more wave action along the eastern shore caused by prevailing winds.

Discussion:

To set the discussion of wetlands in perspective, it should be noted that the lacustrine wetland patterns noted in 1989 are not indicative of wetlands at the lake in previous years. Reports from Mike Cook, the Park Manager indicate that most of the embayments were completely choked with thick mats of aquatic weeds that grew during the summer in previous years, making boating and fishing there nearly impossible. In previous years chemical weed control had to be employed in an attempt to keep these areas open, but in 1989 it was not necessary. There were heavy and persistent rains throughout the spring and summer of 1989. During several of the trips to the lake, it was noted that floating strands of Ceratophyllum and Potamogeton could be seen in the lake water. These had obviously been uprooted and carried out into the lake. It is likely that in 1989 one or more of the following factors may have operated to reduce the area of nonpersistent lacustrine wetland vegetation:

1) Dilution of nutrients by increased inflow to the lake.

2) Unfavorable conditions for the emergence of nonpersistent vegetation in the spring caused by temporarily increased lake depth and water turbidity.

3) Uprooting of some of the nonpersistent vegetation that did grow by extensive flow of storm waters through the embayments.

The above conditions are only temporary and are not likely to repeated with any regularity. It is chiefly the growth of nonpersistent vegetation in the summer that limits the use of the lake by the public and by lakeside residents. Success of this wetland type depends upon the presence of quiet, shallow, nutrient-rich water and sediments, all of which are present in the embayments, and at the upper end of Lake Waveland.

CONCLUSIONS AND RECOMMENDATIONS

Present Conditions at Lake Waveland and its Watershed

The lake is filling in at a rate of 0.1 foot per year. The embayments and shallow areas at the northern end of the lake are choked with floating rooted vegetation most summers. It is estimated that the embayments have lost 25 to 36 percent of their water volume at this point. The depth of sedimentation at the deepest point of the lake is unknown, but it is likely to be less than that of the embayments. An examination of influent stream chemistry indicates that no one stream predominates in the importation of nutrients to the lake. Sediment loads were greater for intermittent influent streams than for perennial streams, but all embayments, whether fed by perennial or intermittent streams were not markedly dissimilar, either in chemistry or sediment depth. The only exception was the embayment described by Transect 1 in which there is much less sediment, apparently due to the presence of the causeway.

An examination of land uses in the watershed indicates that there are no significant point sources of pollution or sedimentation. About 72 percent of the land in the watershed is used for row crop, and about 70 percent of the row crop areas are located on soils with at least some degree of erosion hazard. Major land uses close to the lake are primarily non row crop. Lake Waveland Park does not appear to be a major contributor to the lake water quality problems. Most of the sanitary facilities are on holding tanks, and so long as these are properly pumped and maintained they should not be a source of contamination. The waste water treatment plant for the trailer camping area in the park has not had any operating problems to the author's knowledge. The housing development on the west side of the lake has individual septic tanks for waste treatment. There are no reported problems or complaints with the systems and they are installed mainly in soils with few limitations for septic tank use. The embayment surrounded by most of the residences did not have greater levels of nutrients or vegetation than the other embayments around the lake.

The results of this report suggest that farming and farming practices in the watershed are the greatest contributors to the declining water quality and usability of Lake Waveland, rather than urban, industrial or recreational uses.

Future Conditions of Lake Waveland and Its Watershed

There are no indications that land use patterns in the Lake Waveland watershed will change markedly in future years. There are no urban or industrial areas in the watershed that might expand, nor are there any plans known that would introduce those uses into the watershed. There are no known expansion plans for Lake Waveland Park. Examination of vintage air photos dating back to 1950 indicates that while some areas of pasture in the water shed have reverted to forest and woodlots, there was apparently no change in the overall area of row crop land for the dates examined.

One exception to this may be the further development of residential housing on the west side of the lake. Impacts from housing and septic tanks were not detected during this study, but increased use of septic tanks may lead to additional inflows of nutrients into the lake and increased growth of aquatic vegetation and further reductions in water clarity due to phytoplankton in the embayments on the west side.

Assuming that residential housing does not increase markedly along the west side of Lake Waveland, and ignoring the tendency of proliferating rooted aquatic plants to hasten the infilling process, the embayment areas are estimated to be filled within 40 years, resulting in areas that are largely mud flats or extremely shallow water occupied mainly by cattails, shrubs and willows. Most aquatic habitat will have disappeared, including areas now suitable for spawning for pan fish, particularly bass and bluegill. The embayments are presently acting in part as sinks for sediments and nutrients brought in by the influent streams. These tend to remain in the embayments and are kept out of the main water body of the lake, where they would further reduce water quality. With infilling, the embayments will lose their capacity to retain sediments and nutrients, and the main water body of the lake will suffer accelerating loss of water quality, including increased sedimentation, increased growth of floating and rooted aquatic plants, and increased blooms of phytoplankton, especially blue-green algae, which are already predominant. Although no timetable can be assigned, it is likely that drastic reductions in lake water quality and usability will occur far in advance of final embayment infilling, and may have already done so.

Recommended Land Treatment, Remediation and/or Mitigation Measures

This feasibility study presents initial findings about the water quality of Lake Waveland, the likely agents of water quality decline, and allows some recommendations to be made regarding treatment and/or remediation measures that can be employed.

Land Treatment Measures:

Farming activities have been identified as the chief source of sediments and nutrients flowing into the lake. Land treatment measures can be required by the Waveland Park and Recreation Board for leased farmland within the park boundaries, and can be recommended for landowners and farmers outside of those boundaries and encouraged by cost sharing programs through the SCS. Consultation with Steven Woll of the Montgomery County SCS and Donald Donovan of the Parke County SCS indicates that the Montgomery and Parke County SCS offices encourage and/or cost share the following farming practices:

1) Conservation or no till cultivation methods that leave at least a 40-50 percent residue cover on the ground over the winter. Both Parke County and Montgomery County have cost sharing programs for this. This is probably the most economical erosion reduction method.

2) Employing terraces under the T by 2000 program. This is cost shared in both counties.

3) Using cut and fill operations to divert surface water flow around cultivated fields. This is cost shared in both counties.

4) Use of lowhead detention structures and dry dams in streamways. This is cost shared in both counties.

5) Retirement of farm ground under the CRP program for up to 10 years. The farmer is paid a stipend for doing this.

6) Use of low input agricultural practices to promote the use of herbicides and fertilizer in the amounts needed to grow a crop successfully while controlling overuse. The SCS offices offer consultation on these practices.

7) Crop rotation with legumes

8) Grass waterways and grade stabilization

9) Cover crops

10) Hay planting

11) Filter strips in high impact areas

These practices should be required for farmland leased within the park and strongly encouraged in the watershed whenever possible. Without land treatment measures in the watershed, no other mitigation or remediation measures would be effective.

Any impacts from increasing housing development on the west side of the lake can be reduced by establishing minimum lot sizes based upon typical perc tests for the soils there. This would have to be a joint effort between the Parke County Commissioners and the Parke County Health Department.

Remediation/Mitigation Measures on Lake Waveland:

As indicated in the previous section, no mitigation or remediation measures will be effective without the widescale use of land treatment measures. The following measures are discussed assuming that effective land treatment measures are, or will be, in place in the watershed.

1) No Action. Under a no action remediation alternative, many of the existing nutrients will be recycled, and water quality would degrade further as lake turnover, storms, and floods continue to flush the sediments and nutrients located in the embayments out into the lake water column. With time, it is expected that there would be an overall reduction of nutrients in the lake water column as nutrients are eventually incorporated into the deeper lake sediments, but conditions at the lake would not visibly improve in the near future. Given the present condition of Lake Waveland, summer blooms of algae and macrophytes would be likely to continue to the detriment of lake users over perhaps the next decade or longer depending upon the effectiveness of the land treatment measures. Because of this, the embayments would continue to fill with decaying plant debris and depths would continue to decline.

2) Weed Control. Weed control measures are already in use on the lake. Once effective land treatment measures are in place, weed control methods employing mowing or controlled herbicide applications would become much more effective and would probably be sufficient to correct many of the lake's existing problems. Dead or mowed weeds should be removed from the lake and taken onto land for disposal. This will to a small extent reduce the pool of available nutrients present in the lake.

3) Dredging. Dredging the embayments would have a number of beneficial effects on the lake. First, embayment volumes would be increased and their capacity to capture and retain nutrients and sediments flowing into the lake would be in part restored. Second, increased water depth and decreased nutrients would make the embayments less favorable for rooted aquatic macrophytes and phytoplankton. Third, the embayments would cease to be reservoirs of sediment and nutrients that can be flushed into the lake following disturbances of the water column. Only one episode of dredging would be recommended. The soft consistency and high nutrient content of the sediments make it a certainty that once disturbed, additional nutrients and sediment particles will be transported into an already

eutrophic water body. One or more seasons of diminished water quality and perhaps increased algal blooms would occur in the main lake following dredging.

4) Dredging with Detention Structures. The Lake Enhancement Program at present will not fund any lake dredging operations unless detention structures/nutrient traps are installed upstream from the lake and land treatment measures are employed in the watershed. This would extend the life of the benefits to be derived from dredging. Sediment retention basins at or near the head of each embayment could either be installed within the embayment, or in the stream valley within land controlled by the Little Raccoon Conservancy District. These would retain much of the sediment and nutrient loads carried by influent streams, and could be periodically dredged to maintain their volumes without disturbing the rest of the lake. A separate engineering design study would have to be undertaken and more detailed information would have to be gathered on the flow characteristics and sediment load of each influent stream to properly design the basins and recommend proper maintenance and cleanout. Without this information, unit costs cannot be estimated for basin construction or maintenance.

Cost Vs. Benefits of Mitigation:

1) Dredging:

Dredging is a very expensive process. The following estimates were made of sediment volumes to be removed from each of the embayments:

T-1 - 0 acre-feet

T-2 - 7.8 acre-feet

T-3 - 11.0 acre-feet

T-4 - 23.0 acre-feet

T-5 - 8.8 acre-feet

T-6 - 9.2 acre-feet

Total - 59.8 acre-feet.

Estimated dredging costs are between $4,000 and $6,000 per acre-foot (one acre-foot = 1613 cubic yards) so completely dredging the embayments described above would cost between $240,000 and $360,000, not including the costs of designing and building suitable detention basins, identifying a suitable disposal site, setting up temporary holding areas, and handling, transportation and disposal costs, and any chemical tests of the sediment that might be required. Costs are based upon using a mud cat, or suction dredge. Lake access for a dredge would also have to be checked. Dredging would be a one-time expense if land treatment measures are effective.

2) <u>Weed Control by Harvesting</u>:

In order for weed harvesting to be effective, the weeds must be removed from the lake after they are cut. There are about 8.4 acres of nonpersistent emergents present and a harvester with a conveyor belt can cut the weeds for about $500 per acre for a total of $4,190. These are harvesting costs only and do not take into account the labor involved to move and spread the harvested material, down time to move the harvester around the lake or mobilization/demobilization time. To be effective, harvesting would have to occur every year and would not correct the problem of the nutrient-rich sediments being carried into the lake from the embayments. However access into the embayments would be improved and both the long-tern and short-terms costs would be less.

3) <u>Weed Control by Chemical Means</u>:

Weed control using chelated copper-type herbicides costs about $210 per acre, or about $1,760. However to effective, treatment should be done twice a year, so the yearly cost would be about $3,500. There are two problems with chemical treatments. The first is the toxic effect of the herbicides on birds, fish, waterfowl and invertebrates. The second is the fact that the dead weeds would be left to sink, and so contribute to the nutrient pool in the embayments.

In practical terms, the costs of a dredging program probably exceeds the benifits to be derived. A lake such as this has a recreational life of about 50 years, of which 30 years are left. This means a minimum cost of $12,000 for each year of recreational life left if dredging is employed, a cost which can probably never be recovered.

Weed control by harvesting offers an intermediate cost, and while it does little to reduce the nutrient pool in the sediments, will not replenish the pool. Harvested weeds may be incorporated into the fields on the park by disking, reducing the need for soil amendments. This may have some practical benefits to the lake.

Weed control by chemical means offers the lowest cost of the mitigation methods discussed, but will contribute dead plant material to the sediments. The addition of toxic chemicals to the lake water should be avoided.

Recommendations:

It is recommended that the Waveland Parks and Recreation Board work with the Little Raccoon Conservancy District and the Parke County and Montgomery County SCS offices to encourage the use of the previously discussed land treatment measures both in the park and in the watershed. In addition to this, it is recommended that weed control by harvesting be employed, and that the harvested plant material be placed on shore.

Recommendations for Further Action

1) Land Treatment Measures. Outside of the land treatment measures previously discussed, the only further action recommended would be to work with the SCS offices to contact individual landowners in problem areas to encourage the implementation of specific land treatment measures on their lands, and to make them acquainted with the consultation and cost sharing services offered. The Lake Enhancement Program is currently developing policy and guidelines to

implement a Lake Watershed Treatment Program. Under this program, Soil and Water Conservation Districts could apply for funding to implement watershed land treatment measures when a completed Lake Enhancement Feasibility Study or Prelioominary Investigation has recommended that land treatment measures are necessary for the restoration of the lake. The Lake Watershed Treatment Program should be ready to begin funding projects in 1991.

2) Design and Construction of Sediment Basins. Since this is not a recommended alternative, there are no recommendations for further action.

3) Dredging. Since this is not a recommended alternative, there are no recommendations for further action.

4) Spot Weed Control. The park should investigate the lease or purchase of a harvester for aquatic weed control, or work with contractors who can do the work. It should also determine a location and method for disposing of cut weeds on land.

LITERATURE CITED

Clark, G.D. (ed.). 1980. The Indiana Water Resource. Indiana Department of Natural Resources. Indianapolis. 508 p.

Cowardin, L.M., V. Carter, F.C. Golet and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service. FWS/OBS-79-31. 47 p.

Indiana Division of Water. 1964. Ground-water resources of west-central Indiana. Preliminary Report: Parke County. Indiana Department of Conservation. Division of Water Resources. Bulletin No. 23. 125 p.

Indiana Division of Water. 1965. Ground-water resources of west-central Indiana. Preliminary Report: Montgomery County. Indiana Department of Natural Resources. Division of Water. Bulletin No. 27. 107 p.

Indiana Division of Water. 1974. Ground-water resources of Montgomery County, Indiana. Indiana Department of Natural Resources. Division of Water. Bulletin No. 36. 20 p.

Indiana Stream Pollution Control Board. 1976. Indiana lake classification system and management plan. 178 p.

Soil Conservation Service. 1967. Soil Survey. Parke County, Indiana. Series 1949, No. 12. 95 p.

U.S. Geological Survey. 1983. Hydrology of Area 30, Eastern Region, Interior Coal Province, Illinois and Indiana. Water-Resources Investigation Open-File Report 82-1005. 82 p.

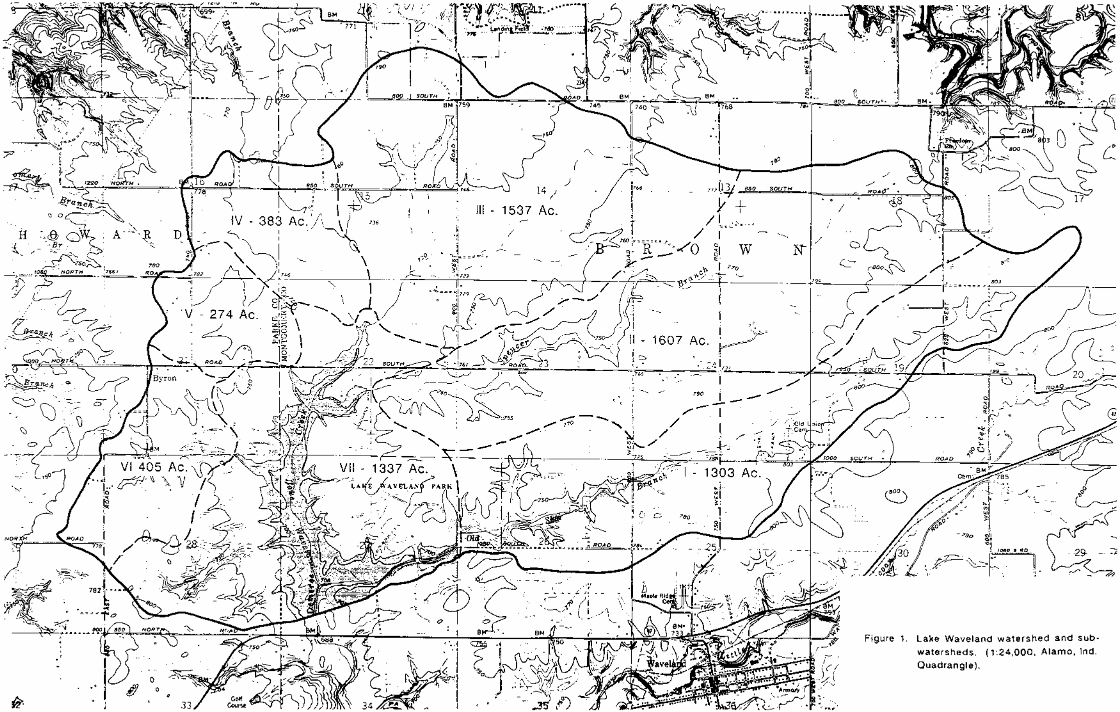


Figure 1. Lake Waveland watershed and sub-watersheds. (1:24,000, Alamo, Ind. Quadrangle).

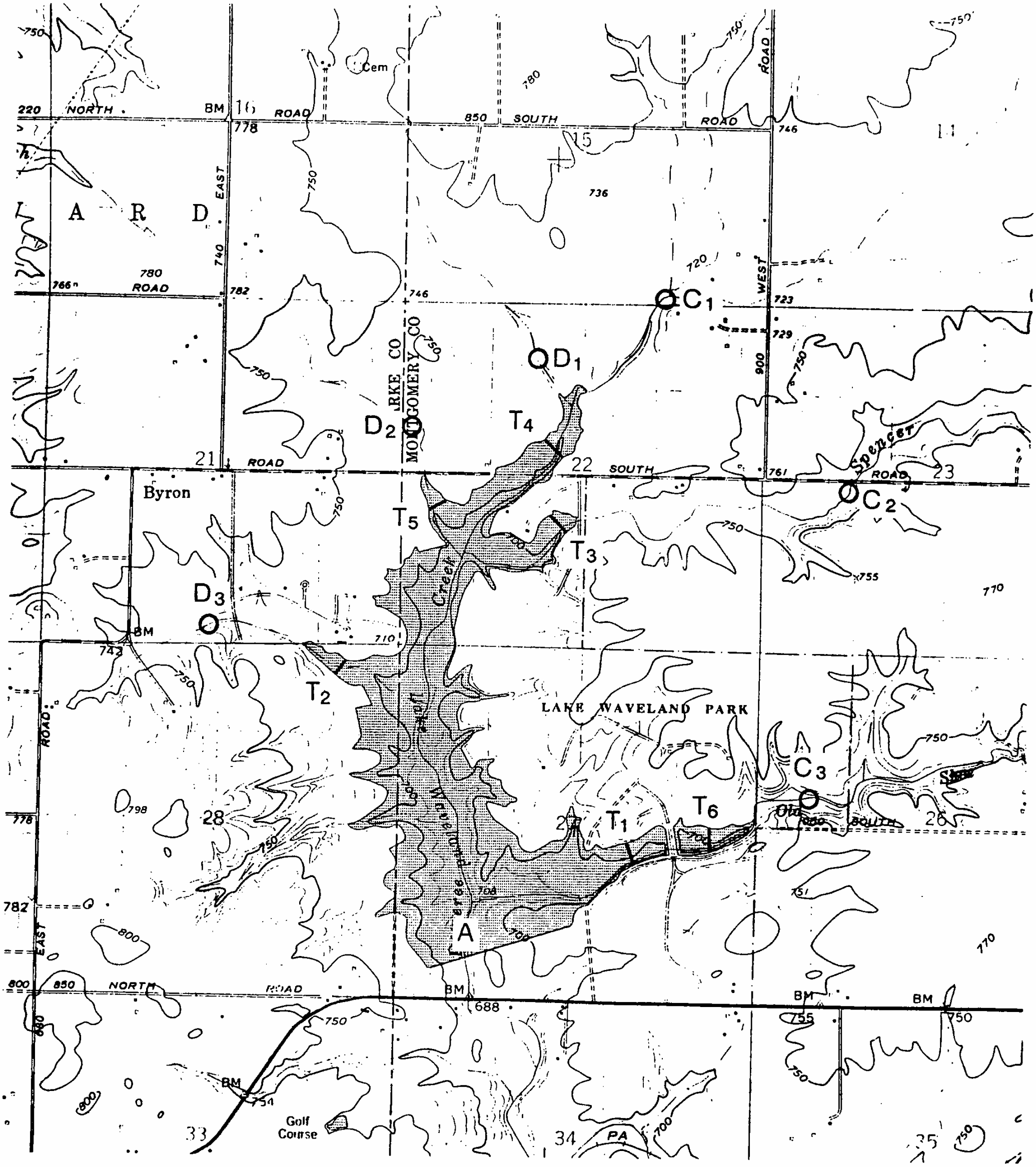


Figure 2. Lake and stream sampling points.

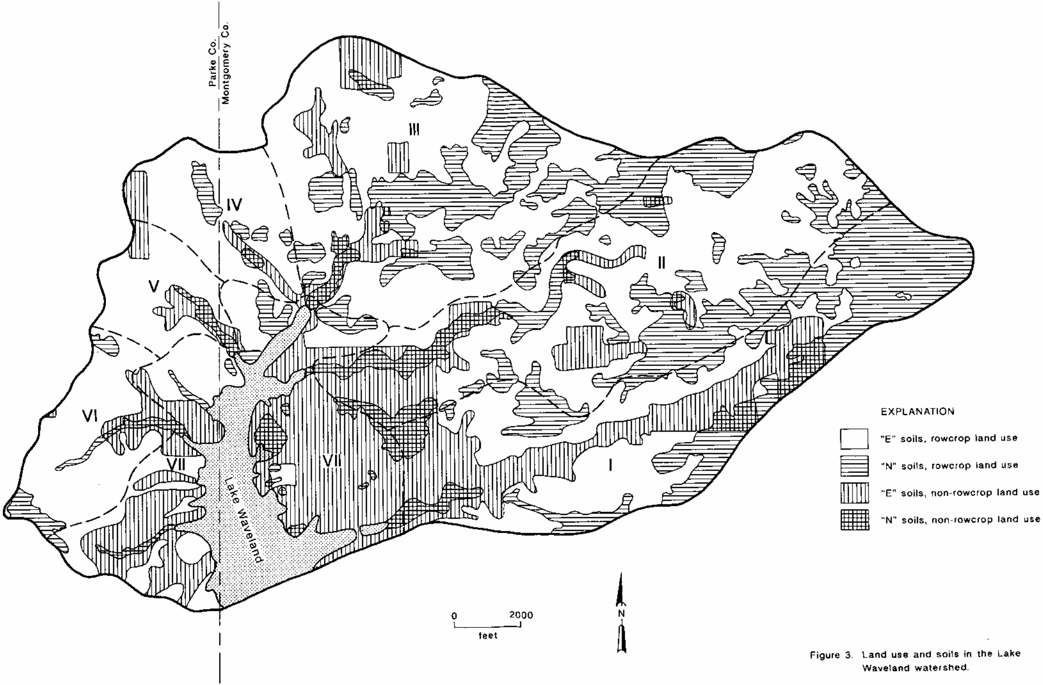


Figure 3. Land use and soils in the Lake Waveland watershed.

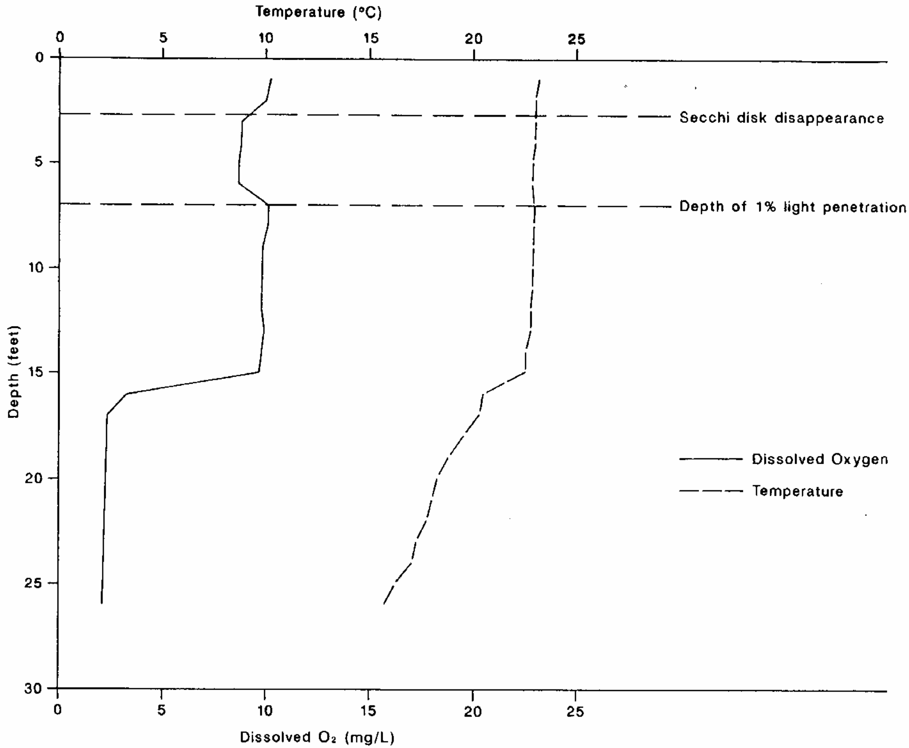


Figure 4. Dissolved oxygen and temperature profiles and water clarity indicators.

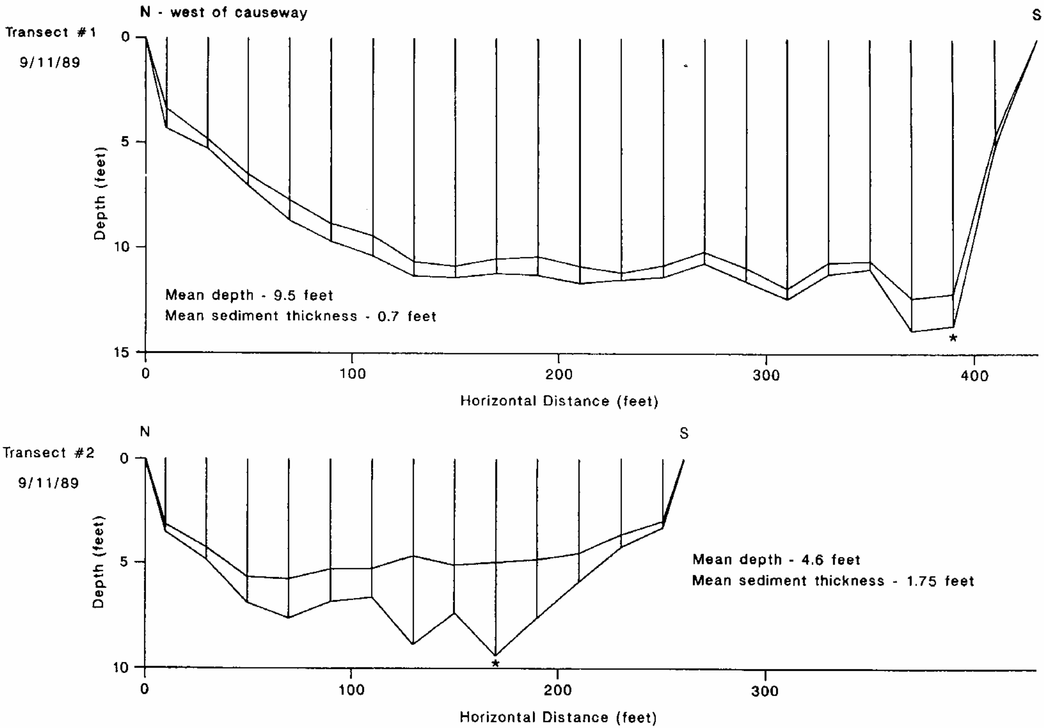
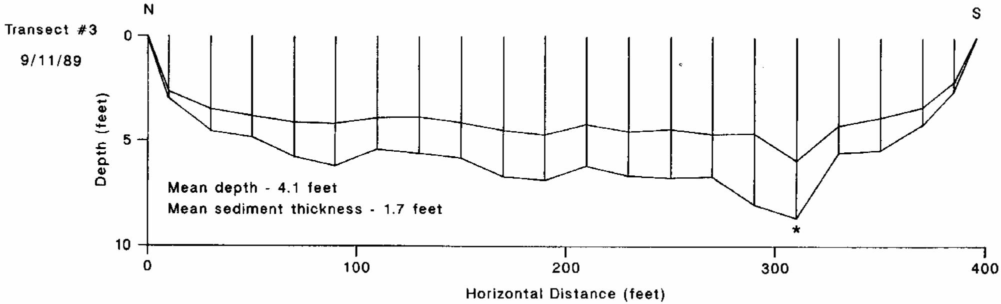


Figure 5. Embayment depth profiles and sediment thickness.



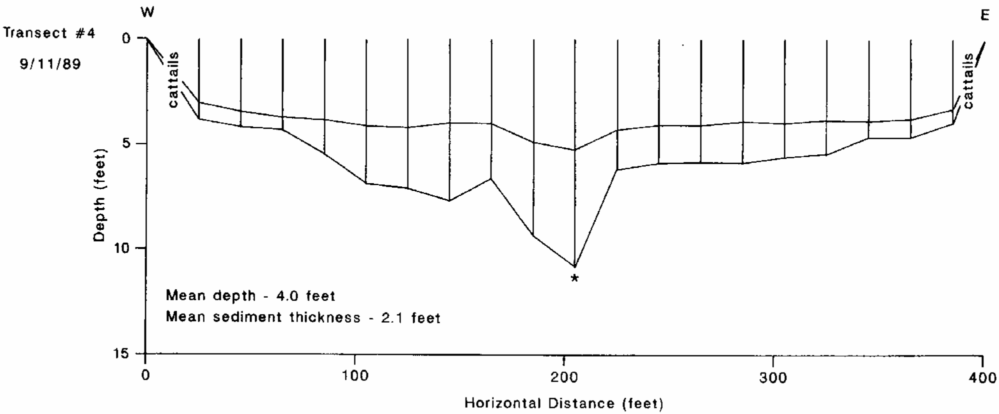
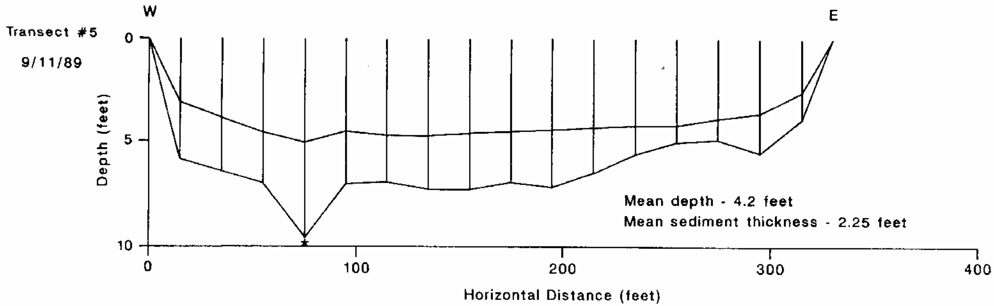


Figure 5. (cont.)



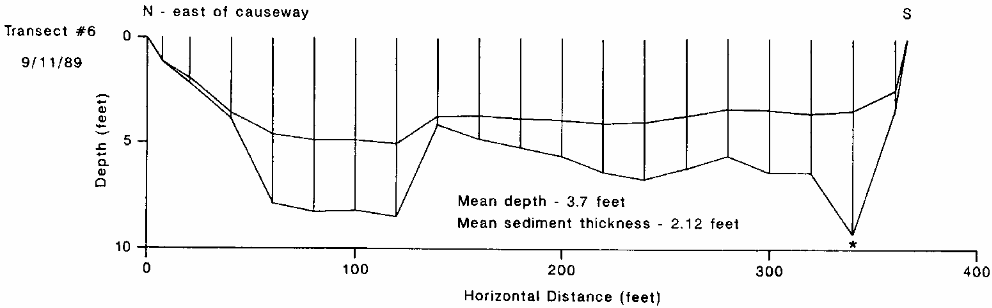


Figure 5. (cont.)

Table 1. List of Parke County and Montgomery County Soils
Mapped in Lake Waveland Watershed

Montgomery County:

Soil Name	"E"	"N"
Beckville Loam		+
Camden silt loam	+	
Hennepin complex	+	
Martinsville-Ockley silt loam	+	
Miami silt loam	+	
Miami clay loam	+	
Miami-Xenia silt loam	+	
Ragsdale silty clay loam		+
Reesville-Fincastle silt loam		+
Russell silt loam	+	
Shoals silt loam	+	
St. Charles silt loam	+	
Washtenaw silt loam	+	
Udorthents	+	
Xenia-Birkbeck silt loams	+	

Parke County:

Soil Name	"E"	"N"
Alford silt loam	+	
Fincastle silt loam	+	
Fox silt loam	+	
Gennessee silt loam	+	
Ockley silt loam	+	
Ragsdale silt loam		+
Reesville silt loam		+
Russell silt loam	+	
Russell soils	+	

Note: "E" soils are those with a listed erosion hazard or potential
"N" soils have no erosion potential listed

Table 2. Land Use Summary

Subwatershed I (Old Shoe Branch) - 1303 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	476.8 acres (36.6 %)	391.0 acres (30.0 %)	867.8 acres (66.6 %)
Non Row Crop	300.9 acres (23.1 %)	134.3 acres (10.3 %)	435.2 acres (33.4 %)
Subtotals	777.7 acres (59.7 %)	525.3 acres (40.3 %)	1303 acres

Subwatershed II (Spencer Branch)-1607 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	865.4 acres (53.9 %)	454.4 acres (28.2 %)	1319.8 acres (82.1 %)
Non Row Crop	202.8 acres (12.6 %)	84.4 acres (5.3 %)	287.2 acres (17.9 %)
Subtotals	1068.2 acres (66.5 %)	538.8 acres (33.5 %)	1607 acres

Subwatershed III (Demeree Creek) - 1537 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	890.2 acres (57.9 %)	482.8 acres (31.5 %)	1373.0 acres (89.4 %)
Non Row Crop	136.0 acres (8.8 %)	28.0 acres 1.8 %)	164.0 acres (10.6 %)
Subtotals	1026.2 acres (66.7 %)	510.8 acres (33.3 %)	1537 acres

Subwatershed IV - 383 acres:

Row Crop	313.0 acres (81.7 %)	32.7 acres (8.5 %)	345.7 acres (90.2 %)
Non Row Crop	32.1 acres (8.4 %)	5.2 acres (1.4 %)	37.3 acres (9.8 %)
Subtotals	345.1 acres (90.1 %)	37.9 acres (9.9 %)	383 acres

Table 2. (cont.)

Subwatershed V - 274 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	248.0 acres (90.5 %)	10.4 acres (3.8 %%)	258.4 acres (94.3 %)
Non Row Crop	12.0 acres (4.4 %)	3.6 acres (1.3 %)	15.9 acres 5.7 %)
Subtotals	260.0 acres (94.9 %)	14.0 acres (5.1 %)	274 acres

Subwatershed VI - 405 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	342.0 acres (84.4 %)	38.2 acres (9.4 %)	380.2 acres (93.8 %)
Non Row Crop	19.6 acres (4.8 %)	5.2 acres (1.4 %)	24.8 acres (6.2 %)
Subtotals	361.6 acres (89.2 %)	43.4 acres (10.8 %)	405 acres

Subwatershed VII - 1337 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	330.7 acres (24.7 %)	44.6 acres (3.3 %)	375.3 acres (28.0 %)
Non Row Crop	881.9 acres (66.0 %)	79.8 acres (6.0 %)	961.7 acres (72.0 %)
Subtotals	1212.6 acres (90.7 %)	124.4 acres (9.3 %)	1337 acres

Lake Waveland Watershed - 6846 acres:

	"E" soils	"N" soils	Subtotals
Row Crop	3466.1 acres (50.6 %)	1454.1 acres (21.2 %)	4920.2 acres (71.8 %)
Non Row Crop	1585.3 acres (23.2 %)	340.5 acres (5.0 %)	1925.8 acres (28.2 %)
Subtotals	5051.4 acres (73.8 %)	1794.6 acres (26.2 %)	6846 acres

Table 3. List of Algae Collected and Relative Abundance

0-5 feet:

	Name	No. Counted	Frequency
CYANOPHYTA			
	Oscillatoria sp.	58	0.513
	Gloeotricha sp.	30	0.265
	Anabaena sp.	4	0.036
	Aphanizomenon sp.	4	0.036
	Lyngbya sp.	2	0.018
	Synechococcus sp.	1	0.008
	Subtotals	99	0.876
CHLOROPHYTA			
	Bumillaria sp.	9	0.080
	Eudorina sp.	3	0.028
	Chlorella sp.	1	0.008
	Subtotals	13	0.116
PYRROPHYTA			
	Ceratium sp.	1	0.008
	Subtotals	1	0.008
	Totals	113	1.000

Estimated density: 11,300 organisms/ml

16-21 feet:

	Name	No. Counted	Frequency
CYANOPHYTA			
	Gloeotricha sp.	119	0.592
	Oscillatoria sp.	64	0.318
	Anabaena sp.	11	0.055
	Nostoc sp.	6	0.030
	Aphanizomenon sp.	1	0.005
	Totals	201	1.000

Estimated density: 20,100 organisms/ml

TABLE 4. Summary of Analytical Data

Location (Figure 2)	Matrix	Date Collected	Flow (cfs)	Total Phosphorus (P)	Total Kjehldahl Nitrogen	Ammonia	Nitrate	Total Suspended Solids
A	Water	8/23/89	-	<0.1 mg/L	2.94 mg/L	<0.40 mg/L	<1 mg/L	-
C-1 (regular flow)	Water	8/21/89	0.083	1.053 mg/L	1.86 mg/L	<0.40 mg/L	1.4 mg/L	12 mg/L
C-1 (storm flow)	Water	8/22/89	0.483	1.778 mg/L	3.92 mg/L	<0.40 mg/L	4.2 mg/L	100 mg/L
C-2 (storm flow)	Water	8/22/89	0.380	1.077 mg/L	4.42 mg/L	<0.40 mg/L	2.9 mg/L	360 mg/L
C-3 (storm flow)	Water	8/22/89	too deep	1.288 mg/L	2.52 mg/L	<0.40 mg/L	3.4 mg/L	400 mg/L
D-1 (storm flow)	Water	8/22/89	0.301	0.912 mg/L	5.04 mg/L	<0.40 mg/L	2.6 mg/L	770 mg/L
D-2 (storm flow)	Water	8/22/89	0.312	0.621 mg/L	<0.40 mg/L	<0.40 mg/L	2.9 mg/L	410 mg/L
D-3 (storm flow)	Water	8/22/89	0.470	1.031 mg/L	4.48 mg/L	<0.40 mg/L	3.8 mg/L	780 mg/L
T-1	Water	9/11/89	-	0.936 mg/L	4.00 mg/L	<0.40 mg/L	3.3 mg/L	-
T-1	Sediment	9/11/89	-	<1.4 mg/kg	160.95 mg/kg	54.12 mg/kg	72.12 mg/kg	-
T-2	Water	9/11/89	-	1.252 mg/L	2.13 mg/L	<0.40 mg/L	<1 mg/L	-
T-2	Sediment	9/11/89	-	9.905 mg/kg	530.20 mg/kg	38.39 mg/kg	191.56 mg/kg	-
T-3	Water	9/11/89	-	1.193 mg/L	2.01 mg/L	<0.40 mg/L	1.1 mg/L	-
T-3	Sediment	9/11/89	-	13.375 mg/kg	580.62 mg/kg	0.59 mg/kg	34.14 mg/kg	-
T-4	Water	9/11/89	-	1.405 mg/L	2.02 mg/L	<0.40 mg/L	<1 mg/L	-
T-4	Sediment	9/11/89	-	8.118 mg/kg	506.98 mg/kg	63.60 mg/kg	309.90 mg/kg	-
T-5	Water	9/11/89	-	1.521 mg/L	1.88 mg/L	<0.40 mg/L	<1 mg/L	-
T-5	Sediment	9/11/89	-	5.275 mg/kg	472.06 mg/kg	73.88 mg/kg	224.78 mg/kg	-
T-6	Water	9/12/89	-	1.556 mg/L	2.12 mg/L	<0.40 mg/L	7.6 mg/L	-
T-6	Sediment	9/12/89	-	16.172 mg/kg	474.76 mg/kg	74.22 mg/kg	113.13 mg/kg	-